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The worst performance rule with elderly in abnormal cognitive decline

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ABSTRACT

Compared to best performances, worst performances on multi-trial psychometric tests often show stronger correlations with other *g*-loaded cognitive tests, which is known as the Worst Performance Rule (WPR). While worst performances may be more sensitive or specific to cognitive decline, clinical psychometric research and neuropsychological practice tends to neglect the WPR. Here, we examined the WPR-paradigm relative to abnormal cognitive decline. Specifically, we studied the WPR with binned simple reaction time task responses when rank-correlated with five different estimates of psychometric *g* within a memory clinic sample (n = 103) of elderly diagnosed with either Mild Cognitive Impairment (MCI) (n = 53) or dementia (n = 50). Three of the *g*-estimates were composite scores constructed from 2, 6, and 28 established test scores. Results showed a consistent WPR-pattern in the whole sample for each of the five estimates (block design r_s = −0.201 to −0.120; digit span r_s = −0.284 to −0.112; *g*2 r_s = −0.311 to −0.162; *g*6 r_s = −0.314 to −0.107; *g*28 r_s = −0.269 to −0.121). Our findings contradict classical test theory, and highlight the underused potential of the WPR when assessing cognitive dysfunction in elderly patients.

1. Introduction

The Worst Performance Rule (WPR) states that worst performances rather than best performances on multi-trial cognitive tasks exhibit stronger correlations with other tests that tap psychometric *g* (Larson & Alderton, 1990). Psychometric *g* denotes the positive manifold of intra-individual test performances (Spearman, 1904) and is considered the principal distillate of general cognitive ability (Jensen, 1998; Johnson, Nijenhuis, & Bouchard, 2008; Spearman, 1927). Worst performances have therefore been suggested as a superior indicator of general cognitive ability, compared to best performances (Coyle, 2003a). Thus, the WPR is an exception to the assumption inherent in classical test theory that responses that deviate from central tendency are less reliable indicators of cognitive ability (Crocker & Algina, 1986). Psychometric evaluations that employ multi-trial tasks may benefit by also considering the WPR when assessing cognitive dysfunction (Coyle, 2003a).

Additional evidence supports a systematic relation between the WPR and *g*. The WPR is strengthened with more complex multi-trial tasks that are more saturated with *g* due to their higher cognitive demands (Fernandez, Fagot, Dirk, & de Ribaupierre, 2014; Jensen, 1982; Kranzler, 1992). The WPR is also more pronounced in subsamples of low intelligence (Baumeister & Kellas, 1968; Coyle, 2003b; Jensen, 1982) which IQs are more dependent on *g*, compared to higher intelligence samples (Detterman & Daniel, 1989; Tucker-Drob, 2009), analogously to *g* and Spearman's law of diminishing returns (Spearman, 1927). Taken together, these findings suggest that the WPR may contribute useful information to different cognitive assessments and their theoretical underpinnings.

Considering aging, *g*, and the WPR in conjunction, available data around the millennial shift suggested that the WPR was exclusively present in children and young adults (Coyle, 2001; Salthouse, 1998). These data harmonized with the Differentiation Hypothesis (Garrett, 1946) and the Theory of Fluid and Crystallized Intelligence (Cattell, 1963; Horn & Cattell, 1966), because these constructs suggest a divergence of cognitive abilities with age caused by mental resources invested into skill specialization leading to a decrease in test performance *g*-loadings from youth and onwards. At the time, data and theory thus supported a WPR-*g* relation that disappeared with age. Naturally, this also rendered the WPR a seemingly unnecessary object of further study in adults and older individuals.

However, more recent research on the WPR indicates that it

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manifests across the life-span on different multi-trial tasks of varying complexity (Fernandez et al., 2014), somewhat exclusively in older samples (Ratcliff, Thapar, & McKoon, 2010). To date, the WPR has found support across several types of multi-trial tasks (Coyle, 2001; Diascro & Brody, 1993; Fernandez et al., 2014) that tap differently labeled yet intertwined constructs such as *g* (Jensen, 1982; Kranzler, 1992; Larson & Alderton, 1990), information processing (Baumeister & Kellas, 1968; van Ravenzwaaij, Brown, & Wagenmakers, 2011), executive function (Fernandez et al., 2014; Unsworth, Redick, Lakey, & Young, 2010), and memory (Coyle, 2001). These aggregate data support Coyle's suggestion of the WPR as a general feature of cognition (Coyle, 2001). Hence, when the goal is to quantify *g*, IQ, or even more specific cognitive abilities with multi-trial tasks across the life-span, it seems viable to also take the WPR into account.

In addition to this seemingly broad applicability of the WPR, there might be specific groups for which it is particularly important. One such candidate group consists of older individuals whose cognitive abilities decline for pathological reasons, and who are consequently diagnosed with Mild Cognitive Impairment (MCI) or dementia. More than a decade ago, (Coyle, 2003a) suggested that the WPR should be studied in clinical subpopulations with attentional deficits, such as ADHD for which an extensive RT literature has accumulated (Tamm et al., 2012). However, WPR studies with other clinical conditions remain scarce. The increased relevance of the WPR across the lifespan, and the often terminal decline of cognitive functioning with dementia-related pathology, suggests that the WPR would be present in such older, clinical samples that may suffer from attention deficits coupled with deficits of information processing, executive function, and memory. These specific cognitive abilities all contribute to *g* and have exhibited the WPR pattern in previous studies (Coyle, 2001; Fernandez et al., 2014; Jensen, 1982). Recent findings also suggest that the WPR is related to attentional lapses that seem to play a key role for executive function and control (Fernandez et al., 2014; Unsworth et al., 2010). Alongside information processing and attention, executive functions are also liable to earliest dysfunction and fastest decline in patients with MCI or dementia (Bäckman, 2008). Since the WPR seems to carry relevant information about several higher-order functions that in turn depend on basic attention, the WPR should have specific clinical assessment potential for these patients.

Most WPR-studies have used reaction time (RT) tasks. RT data consists of multi-trial millisecond responses, whose central tendency and dispersion are both negatively correlated with *g* on the order of 0.2–0.5 (see (Jensen, 2006) for a thorough review). RT tasks vary in complexity, from simple RT (SRT) with only one type of stimulus and one type of response, to choice RT (CRT) tasks with two or more stimuli that require different types of responses. RT central tendency, and RT dispersion in particular, are also positively associated with cognitive dysfunction in MCI and/or dementia patients (Bailon, Roussel, Boucart, Krystkowiak, & Godefroy, 2010; Frittelli et al., 2009; Gorus, De Raedt, Lambert, Lemper, & Mets, 2008; van Deursen, Vuurman, Smits, Verhey, & Riedel, 2009). The WPR has been found across age for CRT tasks (Diascro & Brody, 1993; Fernandez et al., 2014; Kranzler, 1992), and for both low and average intelligence (Jensen, 1982), but not high intelligence (Coyle, 2003b). Furthermore, other metrics that capture worst RT performances have shown predictive power for similar patients, suggesting attentional control as key in discriminating elderly cognitive decline in its early stages (Tse, Balota, Yap, Duchek, & McCabe, 2010).

Despite the weaker SRT-WPR link, we used SRT as multi-trial task in the present WPR study of a memory clinic sample diagnosed with either MCI or mild-to-moderate dementia. The choice of SRT had several aspects to it. It was imperative that these patients could perform the task with sufficient accuracy. Our direct clinical experience suggests that patients with dementia require training before executing CRT but not SRT tasks. Training was not feasible within the present clinical context. Most elderly also lack computer experience, which adds another aversive factor to the already demanding assessment (Wild, Howieson, Webbe, Seelye, & Kaye, 2008), and SRT demands less than CRT in terms of human-computer interaction. SRT is also less influenced by sex and intelligence than is CRT (Der & Deary, 2006) and we also expected that premorbid IQ and education would be higher for patients with MCI, compared to those with dementia. Although SRT tasks have a lower *g*-loading than CRT, this does not explain other findings of the WPR with SRT across the age-span (e.g. Fernandez et al., 2014). Because SRT is a relatively pure measure of basic attention and processing speed (Bailon et al., 2010; Jensen, 1998), SRT also permits more certain inferences about the contribution of these abilities to the WPR. Such inferences may be strongly disputed with more complex multi-trial tasks (e.g. CRT or Stroop-tasks), which also tap other higher-order functions (typically decision making, inhibition). For ethical and practical reasons we also had to keep the RT testing minimal. These patients suffer from abnormal cognitive decline and are already subjected to 2–2.5 h of neuropsychological testing performed in specialized care, a setting not primarily designed for research.

To answer Coyle's (2003a) call for clinical WPR studies, we examined the WPR in relation to cognitive tests in a memory clinic sample of elderly outpatients diagnosed with either MCI or dementia. To the best of our knowledge, this has not been done before. We defined the presence of the WPR as a stronger negative correlation of SRT worst performances compared to best performances in relation to five different estimates of psychometric *g*. Given the previous review and sample chosen, we hypothesized a small but consistent WPR presence over all five *g*-saturated estimates in the whole sample. We also explored the WPR in the MCI and dementia subgroups.

2. Method and materials

2.1. Participants

From 23rd October 2015 to 7th of October 2016, patients were recruited consecutively from those undergoing neuropsychological assessment as part of the outpatient investigation of suspected cognitive dysfunction at one specialized memory clinic in the Stockholm municipality, Sweden. Only those deemed able to give informed consent were asked to participate, and only those then willing were included. A final sample of 103 patients remained after exclusion. See Fig. 1 for the study flow of patients. The present study was approved by the regional ethics committee in Stockholm (Dnr: 2015/1493-31/1) and adheres to the Declaration of Helsinki.

2.2. Procedure

Prior to recruitment at the memory clinic, all patients had been assessed for basal dementia by a primary care physician. This *basic examination* includes anamnesis, evaluation of physical and psychological status, cognitive screening (MMSE and clock test), blood sampling,

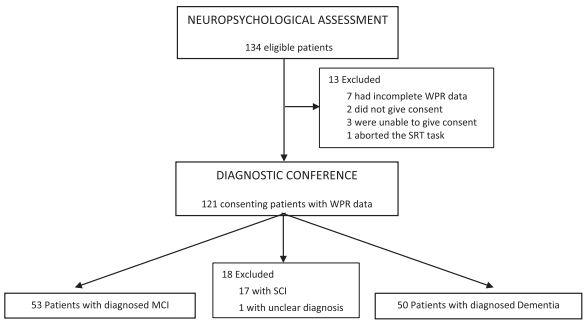

Fig. 1. Flowchart of memory clinic assessment and study inclusion/exclusion. SCI: Subjective Cognitive Impairment (neither MCI nor dementia diagnosis after memory clinic examination).